Road maintenance, road decommissioning, and stream crossing upgrades

Cost of Upgrading Stream Crossings

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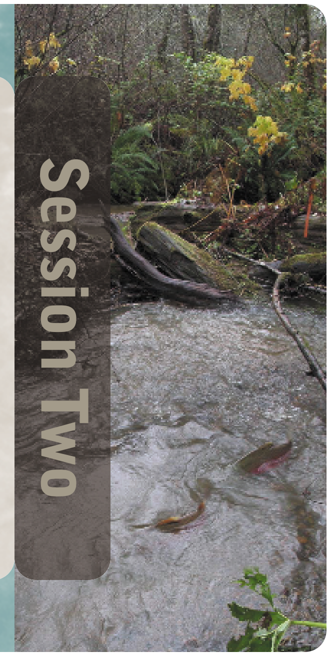
Session Two



ABSTRACT

This paper discusses various alternatives that exist to upgrade culverts so that they will provide acceptable fish passage as well as the costs associated with implementing these alternatives. Most of the streams involved are perennial fish-bearing streams, although some intermittent streams do have fish spawning in the spring when flows are adequate.

INTRODUCTION

Over the past several years the Idaho Department of Lands has been conducting surveys and research to evaluate what impacts are influencing fisheries in Idaho. One of the major impacts we are finding are man made fish barriers that prevent fish from accessing excellent habitat or restrict fish populations upstream of these crossings from having a migratory life cycle. In an effort to reduce the impacts from these barriers, the Idaho Department of Lands as well as other organizations is putting a lot of effort into identifying barriers and determining how to upgrade them. I have been involved extensively in training individuals on how to identify what a barrier actually is and what it takes to provide acceptable fish passage.

I understand these experiences do not exactly make me an expert in dealing with cost issues; however, it's important to realize the Idaho Department of Lands must manage its land first to provide for a secure maximum long term financial return for its beneficiaries. Consequently, cost is always a consideration when designing stream crossings and is something I must always be aware of.

Figure 1 shows a culvert that is a fish barrier. Probably close to 99% of stream crossings that I deal with that impede fish passage are problematic culverts. Consequently, when dealing with upgrading stream crossings, we are really addressing the issue of upgrading culverts so they provide fish passage.

Figure 1. Fish can't get through here?

Before I discuss how to evaluate the cost of upgrading culverts we must first know why a culvert is a barrier in the first place. Different fish passage problems can be solved with different fixes, some of which are much more expensive than others.

There are three main reasons why culverts cause fish passage problems. First, the drop from the outlet is too high. Second, the water velocity through the culvert exceeds a fish's swimming ability, especially in the springtime when rainbow or cutthroat trout are migrating through. Finally, the water depth inside the culvert is too shallow. This is a big issue, especially now that we must size our culverts so that they can pass 50 to 100-year peak flows. When we make that allowance, almost inevitably the water becomes too shallow during low-flow periods. State rules govern what is acceptable for each of these issues. There are numerous alternatives to fixing these passage problems and not too surprisingly depending on which alternative we choose, the cost will vary considerably.

When determining which alternative to use to upgrade a crossing so it provides fish passage the first three things I consider are:

1. What alternatives will provide acceptable fish passage?
2. Which alternatives will meet the traffic needs for the site? For example we wouldn't want to put a ford at a site where we need year round access.
3. What alternatives will have a low chance of failure over the long run? For example if we place materials into the culvert we want to insure the crossing will still allow peak flow events to pass through it.

Once you have a list of alternatives that will provide acceptable fish passage, provide the necessary traffic requirements and have a low risk of failure, it's time to consider the cost of upgrading the culvert. When evaluating the cost of upgrading a culvert I consider the following:

- Cost of materials, including delivery to site
- Cost of installation
- Longevity of structure
- Maintenance of structure

CULVERT UPGRADES

Using those four cost criteria (materials, installation, longevity and maintenance), I will now walk through several alternatives that we regularly consider in Idaho. A cost comparison will tell us which might have the best cost benefit. Note: In these examples, I'm not going to consider the cost of totally removing a crossing and putting in a new one because it is much cheaper to upgrade a culvert in place, wherever practical.

Examples

Angle Iron Fish Ladder

Installing an angle iron fish ladder is one alternative for increasing water depth and slowing water velocity in a culvert. Figure 2 shows such a ladder. When properly installed, the fish ladder will create a step pool sequence throughout the length of the culvert allowing fish places to rest as they migrate through. This particular culvert occurs at about a 5% grade and is about 50 feet long. With that fish ladder in place, even juvenile fish will have no problem getting through.

When we're determining the cost of one of these ladders, we first ascertain materials cost, including delivery to the site. The ladders aren't expensive: $15 a foot for one about four feet wide; for a 50-ft. culvert, that's $750. We usually build these in 15- to 25-ft. lengths, so they can be transported on a flatbed, which runs up to $35 an hour for delivery. Of course, in Idaho this may be cheaper than in other states.

Figure 2. Angle iron fish ladder

In our area, rock typically runs $3 per cubic yard for rock that's a foot in diameter. For each fish ladder, it usually takes a cubic yard of rock per cross member. For a 50-ft. culvert with 10 cross members the total cost for rock will be $30. Loading the rock into the transport truck runs $0.50 a yard, which seems cheap; if we're hauling a lot of rock, the costs can quickly add up. Getting the rock to the site is often the most expensive part. In the example in Table 1, delivery of the rock costs $0.60 per cubic yard per mile (a round trip of 30 miles thus costs about $180). If we're in an area where it's hard to find good rock, that travel distance can double or even triple.

Once everything is at the site, the cost shifts to installation of the fish ladder. Fortunately, installing an iron fish ladder can be done with manual labor in about two hours with experienced supervision. Our going rate for manual labor is $25 per hour. Once the ladder is placed inside the culvert, rock must be placed behind each cross member. This is definitely the hardest part of the installation, and for a culvert with a 4-ft diameter, this takes about 4 hours. Once the rock is in place the top end of the ladder must be chained to a dead man of some sort — either a big piece of rip rap, angle iron or railroad iron. The whole project totals $1,185, which is relatively cheap. Table 1 reflects costs of the actual project for the culvert shown in Figure 2.

Table 1. Angle iron fish ladder average costs

Item	Cost ($)
Materials including delivery to site:	
Fish Ladder 50 ft. long ($15/ft)	750
Delivery on Flat Bed truck ($35/hr)	70
Rock for fish ladder ($3/yd^3) (1/ yd^3 per cross member)	30
Loading rock ($0.50/ yd^3)	5
Delivery of rock – 30 miles ($0.60/ yd^3/mile)	180
Labor for installing the fish ladder:	
Installing fish ladder – 2/hrs ($25/hr)	50
Placing rock – 4/hrs ($25/hr)	100
Total	**1,185**

Chimney Block Fish Ladder

Another alternative is a second type of fish ladder called a chimney block ladder, which operates under the same principle as the angle iron ladder. Here, the cost of material, the chimney block, is the most expensive part. We try to keep the ladders spread 5 feet apart, depending upon the grade of the culvert. In the example in Table 2, the 50-ft.-long culvert received 2 blocks every 5 feet for a total of $100. The main cable that runs the length of this culvert (60 ft.) costs $0.50 a foot for a total of $30. Tether cables that attach the main cables and hold the chimney blocks in place cost $50 for 100 feet plus cable clamps, washers, and a hook to hold everything in place at another $20. One pickup truck can deliver all the materials to the site in a round trip of two hours for a total of $50.

Table 2. Chimney block fish ladder average costs

Item	Cost ($)
Materials including delivery to site:	
Chimney blocks – 2 every 5 ft. ($5/block)	100
Main cable – 60 ft. long ($0.50/ft)	30
Tether cables – 100 ft. ($0.50/ft)	50
Cable clamps, washers, and hook	20
Delivery – 2 hr. trip ($25 p/hr in pickup truck)	50
Labor for installing the fish ladder:	
Labor – 5 hrs. ($25 p/hr)	125
Total	**375**

Again, this is fairly inexpensive for materials and only manual labor is needed for its installation. From experience, it takes about five hours to put in place, adding $125 for labor for a grand total of $375, or one-third the cost of the angle iron fish ladder. In the right situation, a chimney block ladder can be very cost-effective.

Figure 3. Correctly installed chimney block fish ladder

Welding Baffles into Culverts

Baffles are another solution for increasing depth and slowing water velocity in a culvert (Figure 4). This alternative is more expensive than the last two as shown in Table 3. Baffles can be welded into a culvert on site for about $225 a baffle – this includes cost of materials. A 50-ft. culvert with baffles 5 ft. apart would require 10 baffles or $2,250. But it's more complicated than that. To facilitate the welding, the culvert must be dry so a pump and hose are required (rented), the stream is dammed

Table 3. Welding baffles into culvert — average costs

Item	Cost ($)
Weld in baffles – 10 baffles ($225/baffle)	2,250
Pump and hose rental – 8 hrs. ($10/hr)	80
Labor – 8 hrs. ($25/hr)	200
Total	**2,530**

upstream of the culvert and the water pumped around. Typically, 8 hours or a full day are needed to weld all these in place. At $10 an hour, the pump will cost $80 plus 8 hours of labor (to man the pump and make sure the dam functions appropriately) at $25 an hour, or another $200. Now the grand total is $2,530, twice as much as the angle iron fish ladder and six times the cost of a chimney block ladder.

Figure 4. Baffles welded into a culvert

Backing Water into the Culvert (Drop Structure)

An additional technique is backing water into the culvert. Basically, we install a grade-control structure or drop structure downstream from the culvert, which backs water up into the pipe. Figure 5 shows how this technique can greatly slow water velocity and increase depth inside the culvert. This technique can also be used to reduce the drop from the culvert.

This relatively simple alternative has only one required material: rock. A typical project needs about 20 cubic yards of rock; at $3 per cubic yard, that equals $60. The expense comes in loading and hauling that material to the site. The example in Table 4 shows a round trip of 30 miles at $0.60 per mile per cubic yard totaling $360. This becomes expensive if the hauling distance is 100 miles or so. This alternative also requires an excavator, which must be transported to the site. On a low-boy in a 2-hour round trip at $100 an hour, it would add $200 to the cost. In our example, the excavator took 4 hours to complete the task, although that will vary with the size of the excavator and local rates. Last, additional labor costs added $100, for a grand total of $1,180, about the same price as the angle iron ladder.

Figure 5. Backing water into the culvert by use of drop structures

Table 4. Backing water into culvert — average costs

Item	Cost ($)
Materials including delivery to site:	
Rock – 20 yards ($3/yd^3)	60
Loading ($0.50/yd^3)	60
Hauling – 30 miles ($0.60/yd^3)	360
Labor for installing drop structure:	
Mobilization – 2 hrs. ($100/hr)	200
Excavator – 4 hrs. ($100/hr)	400
Manual labor – 4 hrs. ($25/hr)	100
Total	**1,180**

A word of caution: Each of these alternatives will reduce the capacity of the pipe. Most states require that stream crossings pass a certain peak flow event. Hence, if one of these alternatives will reduce the ability of the culvert to pass these peak flow events below what is required by law, they're probably not acceptable alternatives or the crossing will need some additional modifications.

Such modifications that will increase the ability of a crossing to pass peak flows include: putting in overflow pipes if there is a wide enough flood plane, mitering the entrance of the culvert, and raising the road fill over the culvert to increase the amount of head — the higher the head, the more water that can shoot through the culvert. When increasing the head, we must be sure to seriously armor the crossing or there can be serious problems. I've seen a lot of culverts that held year after year in that way, but I've also seen some that have blown out.

It should be noted that, in our area, the Forest Service will also armor the entire crossing. They don't raise the fill, but they have it functioning like a vented ford. In a flood, the water flows over the top of the crossing, but the culvert is armored in such a way that it will stay in place. This is very expensive and those costs are not broken down here.

Cost of Maintenance

For all these crossing upgrades, maintenance is an important issue. At the Department of Lands, we maintain our culverts annually. If there is debris stuck in front or inside the culvert, we remove it; if branches or vegetation are starting to grow in front, they are also removed. When we place materials inside the culverts, that often increases the maintenance costs because debris is more likely to become hung up inside the culvert.

For the most part, maintenance isn't expensive (Table 5). Most often, the annual check-up reveals little or no maintenance needed, so on average, it takes another 15 to 20 minutes of labor per crossing to maintain the angle iron or chimney block fish ladders. At $25 an hour, that's only $10 a year per culvert.

With the baffled culverts, maintenance generally averages less time because we have solid structures. However, when we do have problems, e.g., a piece of wood knocks a baffle out, it costs a lot more to replace it.

Finally, with the drop structure, maintenance runs about $40 per year. The rock structures will shift over time; when that happens, excavators must go in to do the work. In the life of a culvert, it isn't unusual to readjust the drop structures two or three times.

Table 5. Average cost of annual maintenance

Item	Cost
Iron Fish Ladder	$10/yr
Block Fish Ladder	$10/yr
Baffled Culvert	$20/yr
Drop Structure	$40/yr

Maintaining these structures is low compared to the overall cost. But the maintenance needs to be done or more serious and more expensive problems will arise. For those who can't or are not willing to maintain these types of crossings on an annual basis, these aren't good alternatives to consider. Some agencies have so many structures to maintain that they can't check them all. In my opinion, we shouldn't install more stream crossings than we can maintain on an annual basis as that increases the risk of failure.

Longevity

The final thing to consider when looking at overall price is longevity of the structures (Table 6). Over time culverts become dented

Table 6. Longevity of structures

Item	Longevity
Iron Fish Ladder	30 years
Block Fish Ladder	10 years
Baffled Culvert	30 years
Drop Structure	30 years

and they rust through; from bed-load movement, they'll get abrasion or holes punched in them. We're finding these culverts last from 15–60 years, depending on bed-load movement, how corrosive the water is, and the type of traffic. On average a culvert typically lasts about 30 years. When we put in an iron fish ladder, typically it will last the duration of the culvert, about 30 years; with the block fish ladder, however, the chimney blocks will chip or crack so its longevity is closer to 10 years. The baffles should last the entire duration of the culvert as will the drop structure if installed properly.

Putting It All Together: Culvert Upgrades

Table 7 pulls all the cost considerations together for a comparison of the different alternatives (minus the baffle). I did not include baffles because the cost is much more expensive than the others. When developing the overall cost, it is important to consider the interest lost from the money we put into this crossing, in this case, 30 years (30 years because that is the longevity of the most durable structures). Here I used simple interest, because when the Department of Lands does business, they put money into a permanent endowment fund. The money earns interest and that interest is given out to the schools, so it's not rolled back in and compounded. With private individuals, compounded interest is more appropriate. Obviously, the more money spent up front, the more interest is lost over time.

In the final analysis, over 30 years the price of all three alternatives is comparable, with $700 separating the high from the low. In a situation such as this where the overall costs are similar, I recommend selecting the alternative that is going to last the longest and requires the least maintenance. For example, in this case I would suggest putting in the angle iron ladder. If we anticipated that the culvert would have to be replaced in

Table 7. Putting it all together (initial cost + maintenance + longevity)

Cost Item	Iron Ladder	Block Ladder	Drop Structure
Initial cost	$1,185	$375	$1,130
Interest lost (for 30 years)	$2,133	$675	$2,034
Maintenance	$300	$300	$1,200
1st removal/replacement	$0	$574	$0
Interest lost (for 20 years)	$0	$688	$0
2nd removal/replacement	$0	$722	$0
Interest lost (for 10 years)	$0	$434	$0
Total	**$3,618**	**$3,768**	**$4,364**

ten years than the chimney block culvert would be the way to go.

CULVERT REPLACEMENTS

There are many culverts where there is no reasonable way to upgrade them so that they will provide acceptable fish passage, or any upgrades will put the crossing at a high risk of failure. In situations like this, the only practical way to restore fish passage is to remove the culvert and replace it with a fish friendly stream crossing. When replacing a culvert I consider a bridge, a bottomless type culvert, a ford or a properly installed culvert. The cost of each of these crossings can vary tremendously depending on conditions of the site and the design plan. I will go over some of the things to consider when determining the cost of these types of stream crossings.

Bridges

Bridges tend to be the most expensive stream crossing; however, they also tend to be the most fish and environmentally friendly crossings. Typical bridge design constitutes a deck, abutments, footers and wingwalls. The cost of each of these structures fluctuates greatly depending on the type of material used. Table 8 indicates what current installed prices for a bridge are, depending on the type of materials to be used. The deck can be made with steel, concrete, or wood. A wood deck runs $150–300 per foot whereas steel or concrete runs $800 per foot. Decommissioned railroad cars are also available as material; they cost about the same as wood, $150–300 per foot.

Another expensive structure on these bridge designs is the abutment. They hold the whole bridge in place and give it stability. The cost of abutments can vary widely. Wood abutments typically cost about $5000 each installed, +/-$1000. Steel or concrete run about $10,000. Abutments are not needed if we construct a pass through bridge. These bridges span the entire stream channel and rest on footers. Footers cost less than half the price of abutments, but with footers the cost of the deck will be more as the deck must be another 10–15 ft in length so that it can span the entire stream channel. Another consideration in bridge design is wingwalls, usually used with abutments. Wingwalls insure that the abutments aren't undercut by sediment being piped away from them. Again, cost depends upon the type of material used.

Table 9 shows the cost of some of the different bridge designs used in Idaho. The photo examples are of bridges on streams less than 20 feet wide where we typically see culvert problems. Note: These prices include installation, but they don't include a design cost. For my agency, the Department's hydrologist, engineering geologist, and fish biologist do most of the design work; consequently the cost of our work is not factored

Table 8. Average costs of bridge design

Material Used	Deck	Abutments	Footers	Wingwall
Wood	$150–300/ft	$5,000	$2,000	$2,500
Steel/concrete	$500–800/ft	$10,000	$3,000	$5,000
Rock				$2,000
Railroad car	$150–300/ft			

Table 9. Total costs and longevity of four different bridge types

Bridge Type	Total Cost	Longevity
Wood stringer	$10,000–$20,000	25–50 years
Pre-fabricated concrete	$15,000–$25,000	40–60 years
Railroad	$15,000–$30,000	40–60 years
Steel or concrete	$30,000–$50,000	50–75 years

in. If the design is hired out, that cost should be added in.

Wood Stringer Bridge

Figure 6 shows a wood stringer bridge, which ranges in cost from $10–20,000. This bridge is actually on the upper end of that cost range. It's a fairly sturdy structure designed to pass loaded log trucks, and it cost about $18,000 when completed. The issue with wood bridges is their low longevity (approximately 30–50 years); over time the wood tends to rot.

Figure 6. Example of a wood stringer bridge

Prefabricated Concrete Bridge

Figure 7 shows a prefabricated concrete bridge. Basically everything is made in the shop; then it is brought to the site and dropped in place. Prefabricated concrete bridges range from $15–25,000. This one was on the low side at about $17–18,000. The issue here is limited span: the biggest I've seen was about 20 ft long. Larger ones are harder to handle and can break during installation. Their longevity is 40–60 years. Cost of annual maintenance is pretty negligible; in fact, it may not be necessary to go in every year and remove material. However, a wood running surface will only last 15–20 years and costs $1,500 to replace.

Figure 7. Example of a pre-fabricated concrete bridge

Railroad Bridge

Figure 8 shows a railroad bridge, where the rail car was cut in half and laid side by side with gabion abutments under it. Railroad bridges range from $15–30,000 in price, about the same as a wood bridge. Because railroad bridges have a bit longer life span, we rarely put wood bridges in any more. The pictured railroad bridge cost about $24,000 installed. Different vendors sell the railroad cars and price lists are available. Price and quality can vary widely; i.e., if you buy an old beat-up flat car, it will only last about five years.

Figure 8. Example of a railroad bridge

It should be noted that in some states rail cars cannot be used on public roads or forest roads because they don't have design specifications. There is a supplier that upgrades them for such use, but these are a lot more expensive. They have struts underneath and have rails on either side. They don't look like actual rail cars any longer. It is also possible to have rail cars re-engineered for use in crossing projects.

Figure 9 shows a steel or concrete bridge. We have chosen this material a lot lately. Whether steel or concrete, prices range between $30–50,000. This isn't a particularly large bridge; it spans 40 feet or less and cost $45,000 to put in place. The advantage of this alternative is that you can put wood or gravel over it or pave it. Gravel makes grading the road easier; the grader can go right over the bridge and not be slowed down, although he must be careful not to push the dirt off the side. Longevity is 50–75 years, although shifting stream channels might shorten that.

Figure 9. Example of a steel bridge

Other Culvert/Passage Types and Costs

Some additional options for stream crossings include bottomless arches, buried culverts, and fords. Table 10 provides average costs and expected longevity for these additional options.

Bottomless Arch

Bottomless arches are built by digging down outside the stream channel and putting in footers of corrugated metal or concrete (Figure 10). Note that concrete is

Table 10. Cost and longevity comparison for three additional options

Culvert/Passage Type	Cost/ft	Total Cost	Longevity
Bottomless arch	$400–600/ft	$15,000–$25,000	30–60 years
Buried culvert	$150–300/ft	$8,000–$20,000	20–50 years
Ford		$500–$5,000	Varies

much more expensive than corrugated metal. Then, in either case, corrugated metal sheets are added on top. In Idaho, the installed price is $400–600 per foot. The bottomless arch shown in Figure 10 cost about $23,000. Bottomless arches are often cheaper than bridges. However, contractors tend to hate them because they have to be constructed on site and they can be quite difficult to put in. Fine sediment can be a problem because it can erode and undercut the footers and cause the structure to fail. The finer the sediment, the deeper the holes need to be for the footers.

Bottomless arches have a huge range in longevity, with a life span ranging from 30-60 years. Those with a shorter longevity seem to occur in streams with shifting channels, considerable bed-load movement and/or corrosive waters.

Figure 10. Example of a bottomless arch

Buried Culvert

Burying a culvert can be an excellent technique to insure it will provide proper fish passage. Figure 11 shows what the inside of a buried culvert looks like. Notice all the large substrate that occurs in the bottom of the culvert. This substrate mimics a natural stream bottom and will allow even small fish such as sculpin to pass through. This technique works on streams with gradients up to about 5%. Over that grade, it is recommended to install angle iron fish ladders to hold all the rock in place. The installed price for a buried culvert ranges from $150–300 per foot. The culvert shown in Figure 11 was 40 ft. long and was installed for $12,000.

Figure 11. Example of a buried culvert

Longevity for these culverts can vary widely (20–50 years), depending on bed load and the corrosive nature of the water. I recently heard of several culverts that were installed 15 years ago that now have holes in them because of the bed-load moving through. With a buried culvert, abrasion does not occur along the bottom of the culvert as it is protected by rock. The only place abrasion appears is on the sides above the rock line, which tends to increase the lifespan of this type of culvert over what we see with typical culverts.

Ford

The last solution presented here involves fords. While many people denigrate them, I believe they are under-utilized and can be a great alternative, especially on streams with large flood plains or where extensive channel shifting occurs. With a ford, we don't restrict the stream channel, and the only material needed is rock for the approaches. Where we don't need year-round traffic, a ford can be a great alternative. Constructing a ford costs from $500–5,000,

Figure 12. Example of a stream ford

although they can cost much more if the stream grade exceeds 3–4%. In this situation I would not recommend a ford. Typically all that is needed for a ford is to rock the approaches, usually about 150 feet on each side of the stream so that vehicles can clean their tires off before they get to the creek.

Culvert Replacements — Comparison of Options

In a recent real-life example, Idaho Department of Lands compared the cost of installing a steel bridge, a bottomless arch, and a buried culvert. The stream had a V-channel and a lot of bed-load movement. In this situation, the steel bridge had an expected longevity of 75 years, but the bottomless arch had a life span half that because of amount of bed-load. The buried culvert we estimated at 25 years, a third of the steel bridge.

Initial costs were estimated at $45,000 for the bridge, $20,000 for the arch, and $12,000 for the buried culvert. The interest lost period was the full 75 years, the longevity of the most durable structure (the steel bridge). Again, the more money spent up front, the more money we lose in interest over that time. This particular steel bridge had a gravel surface, so the maintenance was very low as described above. The bottomless arch, if built correctly, also has low maintenance since material rarely jams around it. Buried culverts, on the other hand, have a higher maintenance cost,

Table 11. Comparison of options (initial cost + maintenance + longevity)

Cost Item	Steel Bridge	Bottomless Arch	Buried Culvert
Initial cost	$45,000	$20,000	$12,000
Interest lost (for 75 years)	$202,500	$90,000	$54,000
Maintenance	$375	$600	$1,875
1st removal/replacement	$0	$55,200	$28,125
Interest lost	$0	$115,920	$84,375
2nd removal/replacement	$0	$0	$41,250
Interest lost	$0	$0	$61,875
Total	$247,875	$281,720	$269,125

because they do tend to jam with debris more often.

Table 11 shows the rundown of the costs that would be associated with these different alternatives. Over 75 years, the bridge is the cheapest alternative. It also requires the least maintenance, is the most environmental friendly, and has the best longevity.

Note: In many cases, longevity will be considerably higher for buried culverts and bottomless arches, reducing the total by as much as $60–80,000. In that case, the decision is more difficult and we must balance environmental friendliness with cost. A lot of it depends on your policies and preferences. However, if the costs are close in total, I will always lean towards environmental friendliness.

LANDSCAPE APPROACH

I will close with a discussion on evaluating the costs of upgrading culverts in a larger area, such as a watershed or Evolutionarily Significant Unit (ESU).

The first step in determining the cost of upgrading culverts in a large area is discovering how many stream crossings there are. A typical topographic map shows where the roads cross the creeks, but these maps are seldom accurate. The maps seldom show all the roads that exist, so an on-site survey of the watershed is preferred. We did a survey recently in a watershed where maps showed 13 road crossings. We located four additional crossings in this case that were not depicted on the maps.

The next step is to determine which culverts have problems and what are those problems. When in the field, we determine what type of crossings there are, what the stream gradients are (for culverts), the length and size of the culvert, the type of corrugation, the drop into the inlet and out of the outlet, and the depth of the holding pool (Table 12). With this information, we usually can tell which crossings are fish barriers and why. In the watershed survey mentioned above, we found that 12 of the 17 crossings were actual fish-passage problems; i.e., they violated the fish passage rules of our Stream Channel Protection Act.

Once the crossings that are barriers are identified, it's important to consider the size of the watershed upstream, how wide the flood plain is, the grade of the stream, and the other issues identified in Table 12 before we can determine what alternative will work best and be most cost effective. With this information, we can relatively quickly (probably within a day) and easily determine the cost of upgrading the culverts throughout the designated area.

Table 12. What to consider and know when evaluating a stream crossing for fish passage problems

- Type of crossing
- Gradient
- Length and size of culvert
- Corrugation
- Drop into inlet
- Drop from outlet
- Depth of holding pool

However, if we look at a larger area, like a designated ESU, the process becomes more difficult and complex. This is way outside my area of expertise, but after thinking about it for a while here is my thought. First, I would break the ESU into land ownership (U.S. Forest Service, Bureau of Land Management, State, private, and Tribal), and from each of these owners, I would pick 5 to 10 10–20,000 acre watersheds, and go through the process described above, including the on-site reconnaissance. Once 5–10 watersheds had been evaluated, we could expand by ownership for the entire state. It may be necessary to also categorize by state, since different states do business differently.

If you do enough sub-samples you could actually develop confidence intervals around your cost estimates.

A lot of money and effort is currently being put into upgrading stream crossings and I'd just like to reinforce that improving a stream crossing is one of the best ways to increase the range and available habitat for fish. There are significant problems with stream crossings and these upgrades are a good way to use our money efficiently and effectively. Our hope too is that over time, these fixes will help salmon populations rebound.